

(12) United States Patent Haberkamp et al.

(54) GRADIENT NANOFIBER FILTER MEDIA

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(56)References Cited

U.S. PATENT DOCUMENTS

6,746,517 B2 6/2004 Benson et al. 2006/0084340 A1 4/2006 Bond et al. (Continued)

FOREIGN PATENT DOCUMENTS

CN101132907 2/2008 CN 101952210 1/2011 (Continued)

OTHER PUBLICATIONS

International Search Report and Written Opinion for PCT/US2014/ 049434, dated Jan. 22, 2015, 20 pages.

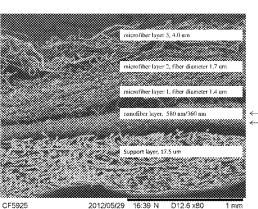
(Continued)

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(57)ABSTRACT

Composite filter media is formed from multiple layers of media material including a nanofiber media layer, where the layers are laminated, bound, or otherwise composited to each other. The composite filter media can comprise at least one nanofiber layer comprising polymeric media material having a geometric mean fiber diameter of about 100 nm to 1 μm, and fibers configured in a gradient such that ratio of the geometric mean diameter of fibers at the upstream face of the nanofiber layer to the geometric mean diameter of (Continued)



First sublayer (580 nm) Second sublayer (360 nm)